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John Fielding Reed

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Chemical Characteristics of the Soils of the Rice Area of Louisiana

by

J. FIELDING REED AND M. B. STURGIS

LOUISIANA STATE UNIVERSITY
AND
AGRICULTURAL AND MECHANICAL COLLEGE
AGRICULTURAL EXPERIMENT STATIONS
C. T. DOWELL, Director

SUMMARY

The coastal prairie soils of Louisiana are used largely for the growing of rice. A study has been made of the chemical nature of these soils and of the chemical and physical changes induced in them by cultivation and flooding.

The more representative soils used for the cultivation of rice were analyzed for total constituents, composition of colloid fraction, and content of available nutrients. This study included some soils that have been repeatedly flooded and cultivated and some that have presumably never been artificially flooded. It also included some soils of the Mississippi bottom and terrace areas.

A comparison of the descriptions and total analyses of the coastal prairie soils with those of some of the soils of the present Mississippi Delta, shows a distinct relationship. The soils are similar in profile characteristics where their positions relative to previous stream action are alike.

Some differences were observed in comparative analyses of the surface layer of a continually cultivated Crowley soil and of a virgin Crowley soil from an adjacent area. The cultivated Crowley was definitely more alkaline and lower in total nitrogen, total phosphorus, and available phosphorus.

Quantities of virgin and of cultivated Crowley soils were kept both flooded with distilled water and under optimum moisture conditions at a consant temperature of 30° centigrade in two-gallon pots. To determine the influences of flooding on the hydrolysis of the complex silicates, samples of soil were withdrawn at regular intervals and analyzed for certain water soluble constituents. In the case of the flooded pots, similar analyses were made at the same time of the displaced liquid obtained by opening the pots at the bottom long enough to collect some of the solution. The changes that were induced by flooding the virgin soil with distilled water were an increase in pH, an increase in the soluble sodium and magnesium, and an increase in the contents of iron and silica in the displaced solution.

The effects of repeated cropping and flooding on the physical condition of the Crowley soil were measured by determinations of the structural aggregation of the soil and the rate of water percolation through the soil. In an attempt to improve the physical condition various treatments were applied to the deflocculated soil in lysimeters. The treatment most effective in increasing the rate of water percolation and building up structural aggregation was the addition of leguminous organic matter in the form of chopped soybean plants. Treatments of lime, gypsum, and elemental sulphur were much less effective.

CHEMICAL CHARACTERISTICS OF THE SOILS OF THE RICE AREA OF LOUISIANA

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INTRODUCTION

Certain changes in the chemical and physical characteristics of the coastal prairie soils have been induced by the long-continued practice of growing rice under flooded conditions. The work reported herein is concerned with the inherent chemical nature of the soils and the chemical and physical changes that take place as a result of irrigation practices. In the first place, the chemical characteristics of the most representative soils of the rice area of Louisiana have been determined. Secondly, the most widely occurring soil, the Crowley silty clay loam, has been studied by comparing the properties of the soil from an area that has never been artificially flooded with those of the soil from an area that has been continually flooded in growing rice. A chemical investigation of the conditions and constituents before and after flooding was conducted in order to determine the effects of flooding. The changes in the physical structure of the soil were studied by determining the amount of structural aggregation and the rate of water percolation through the soils under various conditions. The effects of various treatments on the physical condition were investigated in order to estimate the practicability of such treatments in the field.

REVIEW OF LITERATURE

Recognizing the need for more extensive investigation of the rice soils of Louisiana, Fieger and Sturgis (6) * began a study of the morphology and genesis of the soils of this area and the effects of current methods of agricultural practice upon the chemical, physical and biological properties. This preliminary study included the evaluation of replaceable bases, base exchange capacity, H-ion concentration, soluble salts, and soluble alkali in eight soil profiles of the coastal prairie area of Louisiana. It was observed that irrigation of the soil caused an increase in the total exchange capacity and an increase in alkalinity in the restricted areas studied. The soluble alkali content was low, and in the case of the soils which had not been irrigated, no free alkali was present. It is suggested that the increase in alkalinity may be due to the hydrolytic action of water itself, alone or in combination with monovalent basic ions, and that there is an increased hydrolysis due to prolonged flooding, with the liberation or solution of sodium ions, which have produced in some cases a partial sodium soil with the resultant changes in physical properties.

There are many conflicting statements concerning the chemical consequences of flooding. The fact that they are conflicting is probably due largely to differences in the chemical characteristics of the soils and irrigation waters in different locations. Bartholomew (2) found that irrigation of rice in Arkansas had a tendency to reduce the acidity of the soils, in some cases rendering them alkaline. He attributed this

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* Figures in parentheses ( ) refer to *Literature Cited*, page 30.

increase in pH to the use of waters from wells in limestone which carried annually from 98 to 360 pounds of calcium and from 30 to 60 pounds of soluble iron and aluminum to each acre of irrigated soil. Jansen and Metzger (13), also working in Arkansas, noted a decided change of the flooded soils toward alkalinity in the cases of treatment with green manure, with sodium nitrate, and in the case of the flooded soil receiving no treatment; in the flooded soil treated with ammonium sulfate this tendency was not detected. In a later publication Metzger (21) expressed belief that the accumulation of ammonia due to the anaerobic conditions is partly responsible for the change of reaction toward alkalinity during submergence of the soil with water.

According to Dennett (4) the large differences between concentration of H-ion in rice soil during fallow and when flooded were due not only to the formation of ammonia on waterlogging, but also to a change in the equilibrium between ferrous and ferric ions. Attention was drawn to the possibility that ferrous ion acts as a base. Conner (3) studied the effect of moisture content of the soil upon acidity as determined by the different lime requirement methods. The acidity of the soil was found, in general, to decrease in the case of soils kept saturated with water. Subrahmanyan (34) measured the hydrogen-ion concentration of soil submerged by water. He found a progressive decrease over a considerable period of time and an increase in free and saline ammonia.

On the other hand, Novelli (24) reports that after three to four years of rice cultivation, Vercellese and Bolognese soils increased in acidity. The increase in acidity was attributed to deposits of organic matter from irrigation waters and to crop residues. Itano (11), in Japan, found that although the soil reaction became alkaline after the application of fertilizers, it became acid toward the end of the season.

It is evident that the tendency of the reaction of the soil to become either acid or alkaline after continuous cropping to rice and submergence has been variously explained, depending largely on local conditions. It is interesting to note here the tolerance of rice to acidity or alkalinity. Miyake (23) reports that a high concentration of either the H-ion or the OH-ion is injurious, more so than a high concentration of the Na-ion or the SO_4- or Cl-ions. Mitra and Phukan (22) found that a pH of 3.9 or lower was distinctly toxic. At greater acidity than pH 6.0, the development of roots was below normal, but at less acidity, it was quite satisfactory. The best root growth was attained at pH 7.9, but a drop was found to occur at pH 8.4. On the other hand, Aso's work with pot and water cultures showed that the optimum pH for rice is about 4.0 (1). According to Itano and his associates in Japan (12) the pH values of the soils play an important part in the growth of rice. They also found the optimum pH to be 4.0. Doyne and Glanville (5), working with some swamp rice soils of Trinidad, observed a pH of below 3.0 in most instances. The soils contained free HCl and effervesced when treated with calcium carbonate. In spite of the high acidity, rice grew well on all of these soils. Tzyurupa and Bezruchenko, working in Kuban, were able to find no correlation between the pH and injurious effects in rice soils (35).

That a change in the acidity or alkalinity in the soil may be associated with submergence during rice culture is evident from the above review. Some investigational work has been carried on in various parts of the world on other and more fundamental chemical changes resulting from flooding a soil. In Hawaii, Kelley (18) found the solubility of substances in submerged soils abnormally high. The amounts of iron, manganese, lime, magnesia, phosphoric acid, bicarbonates, silica, alumina, and potash going into solution were found to be considerably greater than were obtained from any of the dry land soils of the island. After the wet soil was allowed to dry out thoroughly, however, the solubility of these constituents in water was found to be greatly decreased, falling to about the same degree as that of dry lands.

Robinson (31) worked on some chemical phases of submerged soil conditions. Submerged soil solutions were radically different from aerated soil solutions in that they contained high concentrations of iron and manganese. The iron and manganese were present as "proto bicarbonates." Submerged soils were also high in calcium and magnesium and contained H_2S and other sulfides, in some instances toxic concentrations of ferrous iron and sulfides developing within a few days after submergence. Robinson found, however, that in the absence of organic matter the solubility of iron, manganese, calcium and magnesium did not increase under submerged conditions.

In studying the effects of irrigation or water-logging on the intensity and products of reduction, Sturgis (33) found that the development of a low oxidation-reduction potential was largely dependent upon the decomposition of active organic matter in the soil, the addition of fresh organic matter to submerged soils causing a rapid lowering in the Eh and some increase in pH. Although the addition of organic matter to the soils that were flooded markedly increased the accumulation of soluble reduced iron and manganese and increased the amount of sulfides, the organic matter also greatly increased the yield of rice.

Very extensive studies have been made within recent years at the Rice Branch Station in Arkansas on the soils of the rice area and the changes effected by submergence. Metzger (21) at that station investigated the effect of moisture content upon the amounts of replaceable bases extractable with 0.04 N hydrochloric acid. Replaceable sodium and potassium were not significantly influenced by the water content of the soil; calcium was slightly decreased by flooding; while magnesium, aluminum, iron, manganese, and ammonium were greatly increased.

Kapp (14, 15) analyzed the rice soil solution and found that it did not contain sufficient quantities of soluble salts to prove harmful in the nutrition of rice plants. Determinations were also made of the manganese and iron contents of soil solutions drained from the soil growing a crop of rice. In later soil solution studies, Kapp's (17) results indicated that in treatments where the production was low, large amounts of soluble iron occurred. The manganese content was not as great as the iron. The need for stressing the unreliability of various methods for obtaining soil solutions for chemical determinations was emphasized by Kapp (16, 17). His results indicated that the submerged soil solution changed with ordinary methods of handling. The amount of calcium, magnesium and iron precipitated out of the drained solution was in some cases very large. The release of carbon dioxide from soils suggested that this gas was responsible for many erratic results connected with submerged soil work. The amount of free carbon dioxide released in some cases is also very large. The effects of stirring, aerating, and filtering suggest that any study of submerged soils must be interpreted with caution.

EXPERIMENTAL PROCEDURE

Morphological studies were made in the field and samples were taken of the profiles of the following soils: Sharkey clay loam, Harris silty clay loam, Iberia silty clay loam, Lake Charles clay loam, Crowley silty clay loam, Olivier silt loam, Calcasieu very fine sandy loam, and Katy very fine sandy loam. The physical description of each soil is given with its chemical analysis under Experimental Results.

A total analysis was made of the soil profile by horizons. The method followed was that used by the Bureau of Chemistry and Soils (30). The colloidal fraction of each horizon was determined by the pipette method (25). The colloidal material used for the estimation of the molecular ratio of silica to sesquioxides was obtained from the fine earth which had been broken by a rubber pestle and passed through a two-millimeter sieve. Thirty grams of soil were shaken over night with 350 milliliters of 4 per cent ammonium hydroxide in a 500 milliliter bottle. The suspension was transferred to a large cylinder, made up to three liters with distilled water, stirred mechanically for 30 minutes, and then allowed to settle for 32 hours. The upper 10 centimeters were carefully siphoned off. The residue in the cylinder was again made up to three liters with distilled water and the stirring and siphoning repeated. This operation was repeated until the upper portion was only slightly opalescent. The combined extracts were evaporated to dryness and the resulting colloids broken up to pass a 100-mesh sieve. The soil colloids were then analyzed for loss on ignition, silica, iron, and aluminum by the fusion method of Robinson (30).

The "available" nutrients in each horizon of the soils were determined according to the method of Reed and Sturgis (28) based upon extraction with 0.05 N hydrochloric acid. Exchangeable hydrogen and degree of saturation were determined by the use of 0.2 N barium acetate solution. The pH was determined in the field and in the laboratory, since some of the soils were found to be more acid on drying. In the field, the La Motte-Morgan block was used. In the laboratory, pH was determined by means of the glass electrode.

In addition to the physical and chemical studies of the soils in more or less normal state, an investigation was made of the changes induced by flooding the Crowley silty clay loam, the most widely occurring soil in the rice area. A comparison was made between virgin soil which presumably had never been artificially flooded and soil from one of the experimental fields at Crowley, Louisiana, that had been continuously flooded and used for rice cultivation over a period of forty years. In order to determine the effects of water on changes in the soil, 5000-gram portions of virgin and of cultivatd soils were weighed out into two-gallon stoneware pots and variously treated. Duplicates of each treatment were kept at optimum conditions of moisture, and other duplicates were kept submerged under six inches of distilled water. Organic matter added was in the form of chopped soybean plants. The treatments were as follows:

1. Virgin soil at optimum moisture.
2. Virgin soil flooded.
3. Cultivated soil at optimum moisture.
4. Cultivated soil flooded.
5. Cultivated soil plus 0.5 per cent organic matter at optimum moisture.
6. Cultivated soil plus 0.5 per cent organic matter flooded.

At the time of setting up this study the pH and the water soluble Ca, Mg, K, Na, Fe, Al, and SiO_2 were determined on all treatments. The pots were then placed in a constant temperature room at 32 degrees centigrade and the same determinations repeated at three- to six-week intervals to ascertain what changes had occurred. Distilled water was used to maintain the optimum moisture and flooded conditions. The pH was determined by means of the glass electrode assembly. It was almost impossible to obtain a clear solution for the determination of water soluble constituents because of the tendency of the soil to deflocculate and of the rather high content of colloidal silica. To reduce the results to a comparative basis, the equivalent of 50 grams of dry soil was removed from the pots by means of a sampling tube and agitated with 250 milliliters of distilled water for one hour. The suspensions were then filtered on a C. S. and S. folded filter No. 588, a mat of soil was thrown down on the filter as an aid, and the first few milliliters were poured back through the filter. The filtrate was then centrifuged, using about 2500 to 3000 r.p.m. in an International Centrifuge. Even after this treatment there was, in most cases, some colloidal matter in suspension. The suspension was used in this condition, however, and the residue after evaporating and taking up with hydrochloric acid was termed silica. The remaining constituents were determined by the methods outlined in Standard Methods of Water Analysis (36). To insure the accuracy of the rather long and involved standard procedures for sodium and potassium, the determinations of these two constituents were checked by other methods. Sodium was determined by the magnesium uranyl acetate method as recommended by Piper (26), and potassium by Schueler and Thomas's modification of the sodium cobaltinitrite method (32). At the same time that these samples were taken for analysis, studies were made of the displaced solution from the flooded pots. This displaced solution was obtained by removing the stoppers from the holes in the bottom of the pots and collecting enough of the percolating solution for analysis. The same determinations were made on this displaced solution as on the extract above. In this case, however, the soil acted as a filter itself and the solution appeared clear. It was, therefore, analyzed directly without further filtration or centrifuging.

As a continuation of the second phase of the study, an attempt was made to measure the physical changes induced by continuous cropping and flooding. Aggregate analysis has been considered as probably the best method for determining real soil structure. In the analysis measurements were made of the water-stable soil aggregates, which are the fine crumbs or granules that are not completely broken down to individual particles when the soil is slaked in water. These particles or granules after slaking are considered to represent the ultimate natural structure of soils, because they appear to be stable and require the application of external energy or dispersing agents to break them up further.

In this work on detection of differences in physical structure in the rice soils by aggregate analysis, an apparatus was used which embodied the principles of that of Yoder (37). In brief, the apparatus consisted of a cylindrical container into which could be inserted a screen frame which held a set of brass sieves. This screen frame was suspended from an arm so that it could be raised and lowered through a distance of $1\frac{1}{4}$ inches. By means of gears and a variable speed motor, the rate of oscillation could be controlled and was adjusted to a rate of 30 oscillations per minute. The sieves were five-inch brass-framed sieves with openings of 2 mm., 1 mm., 0.5 mm., 0.25 mm. (60 mesh), and 0.10 mm. (140 mesh). In operation, 50-gram samples of air-dry soil were placed in the top sieve, the nest was lowered into the container of water and adjusted so that the top screen just remained covered with water when the lift mechanism was at top dead center. The oscillating was carried on for thirty minutes, the sieves were drained and dried, and the various separates were weighed. In order to arrive at a measure of the existing difference in the physical conditions of the cultivated and the virgin Crowley soils, an aggregate analysis of each was made.

To determine the effects of various materials on the physical condition of the rice soils of Louisiana, a lysimeter set-up was arranged consisting of 8-liter pyrex percolators filled with Crowley soils that had been variously treated. These lysimeters were so arranged that percolation could be measured over an extended period of time. They were planted to rice and studies were made of the rate of percolation through the soil and of the soluble constituents in the percolate throughout the growing season of rice (33). To find what effects these treatments for physical improvement would have on the growth of rice, the rice was cut when mature and the comparative yields determined. Measurements of rate of percolation were then continued on the soil in the variously treated lysimeters, and the above outlined method of aggregate analysis was applied in an attempt to arrive at a more definite measurement of the actual state of structure following the treatments.

EXPERIMENTAL RESULTS

Chemical Studies of the Soil Profiles

The geologic origin of the coastal prairie soils of Louisiana has been explained by two theories. The older viewpoint, which has been more generally accepted and was recognized by Marbut (20) and others (19), (29), was that the soil had been developed from recently uplifted calcareous clays of gulf origin. The newer theory of the origin of this area, proposed by Howe and other geologists in Louisiana (8), (9), (10), maintains that the material is alluvial and was laid down by the Mississippi River or older distributaries, either during the last half of the Wisconsin glacial advance, or by lateral migration accompanying the formation of the present delta at some time since the last glacial stage. These investigators are convinced that the prairie region of southwest Louisiana was an ancient delta deposit. When photographed from above, this vast area, which to the eye is practically level, and which is always spoken of as prairie, shows unmistakable scars left upon it by the Mississippi. According to Howe, it is traversed by meanders and natural levees of the ancient river itself and of numerous distributaries, streams much larger than the present Vermilion, Mermentau, or Calcasieu rivers.

The materials from which these soils have developed are of very recent geologic origin, and the soil profiles are not in general well developed. It is interesting to keep the above theories of geologic origin in mind when examining the results of the total analyses of the soils of the coastal prairies. In the first ten tables which follow are given descriptions of the profiles of the soils used for rice, together with total analyses, analyses for available constituents, and analyses of the colloidal fraction. They are presented in the logical order, considering the relationships of the soils one to the other. The first soil listed, a Sharkey clay loam (table 1), is a Mississippi first bottom soil on which approximately forty-thousand acres of rice are grown. According to the Marine theory of origin, the Sharkey soils have little or no relation to the prairie soils, while according to Howe's theory, they would be of similar origin though much younger. The Sharkey soils are, as a rule, much more productive than any of the prairie soils. By comparing the analyses of the Sharkey clay loam, both total and available, with those of the prairie soils (tables 1-10), it appears that, if they were of similar origin, the former alluvial deposits were of a different nature from those being laid down at the

TABLE 1. ANALYSIS OF SHARKEY CLAY LOAM*

	Sharkey A Per Cent	Sharkey B Per Cent
Total analysis:		
SiO_2	72.00	62.7
TiO_2	0.25	0.33
Fe_2O_3	5.32	6.15
Al_2O_3	13.16	19.13
MnO	0.067	0.069
CaO	2.41	2.68
MgO	1.30	1.65
K_2O	0.86	0.97
Na_2O	0.85	0.69
P_2O_5	0.28	0.24
SO_3	0.12	0.08
Cl	0.028	0.025
Ignition loss	4.15	5.22
Colloid analysis:		
Colloid fraction	32.40	56.08
Ignition loss	9.74	9.16
SiO_2	53.04	53.12
Fe_2O_3	7.50	7.34
Al_2O_3	23.14	22.28
Mol ratio $\frac{\text{silica}}{\text{sesquioxide}}$	3.18	3.30
Available nutrients:		
Total N, per cent	0.108	0.119
0.05N HCl Soluble K, ppm.	460	300
0.05N HCl Soluble Ca, ppm.	4600	5020
0.05N HCl Soluble Mg, ppm.	468	634
Available phosphorus, ppm.		
1:10 Soil: acid	30	42
1:40 Soil: acid	132	152
1:100 Soil: acid	330	250
1:100 Soil: water	10	7
Exchangeable H+, m.e./100g soil	0.68	0.68
Total exchange, m.e./100g soil	27.9	43.6
Degree of saturation, per cent	97.6	98.4
pH	7.4	7.6

* Sharkey clay loam—Typical Mississippi River first bottom soil sampled in the fields of the Louisiana Agricultural Experiment Station, East Baton Rouge Parish:

A. 0-8 inches. Dark gray to grayish brown, mottled with rusty brown clay loam, somewhat friable.

B. 8-24 inches. Dark or bluish gray, mottled with rusty brown, tenacious and plastic heavy clay, the mottling increasing slightly with depth. The line of demarcation between A and B is fairly distinct, but there is no sharp line of demarcation between B and C horizons.

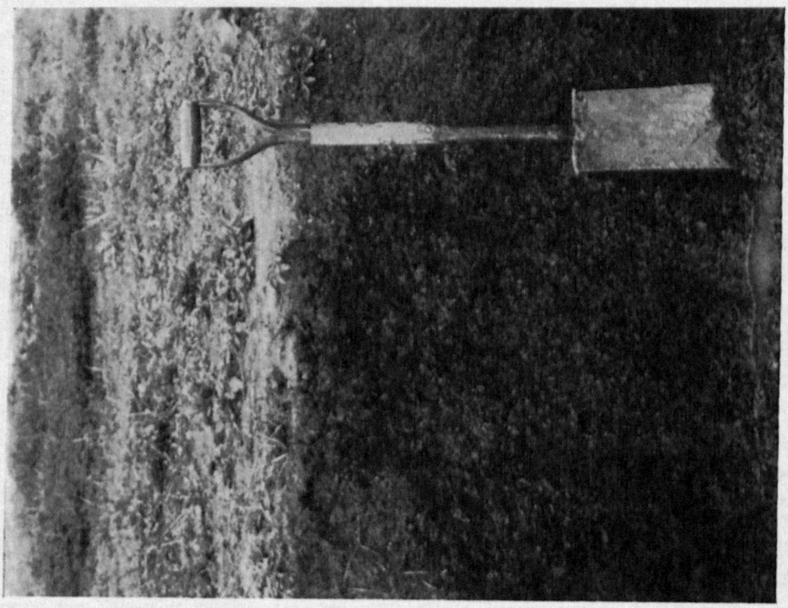

FIGURE 1. SHARKEY CLAY LOAM

FIGURE 2. IBERIA SILTY CLAY LOAM

present time. The phosphorous content, in particular, is unusually low in all of the soils of the coastal prairie, even in the C horizon, while it is quite high in the Sharkey soil. On the other hand, the actual appearances and profile characteristics of the soils seem to follow a definite gradation from the Sharkey at one extreme to the Katy or Calcasieu at the other.

The Harris series (table 2) occupies strips of lowland adjacent to the waters of the Gulf. Soil development has not continued for a sufficent time to produce well developed profile characteristics. The water table lies near the surface, and the soil remains wet for months at a time. This series in Louisiana is not unlike certain

TABLE 2. ANALYSES OF HARRIS SILTY CLAY LOAM*

	Harris A Per Cent	Harris B Per Cent	Harris C Per Cent
Total analysis:			
SiO_2	79.50	87.20	82.30
TiO_2	0.21	0.25	0.25
Fe_2O_3	2.35	1.63	2.61
Al_2O_3	10.20	6.90	9.89
MnO	0.026	0.008	0.008
CaO	1.50	1.61	1.50
MgO	0.67	0.61	0.55
K_2O	1.72	1.08	0.95
Na_2O	0.42	0.28	0.11
P_2O_5	0.050	0.007	0.007
SO_3	0.44	0.29	0.36
Cl	0.055	0.060	0.030
Ignition loss	4.30	1.40	2.43
Colloid analysis:			
Colloid fraction	28.00	18.40	29.66
Ignition loss	11.10	7.42	7.34
SiO_2	49.86	53.80	52.32
Fe_2O_3	7.18	7.26	7.34
Al_2O_3	22.22	22.62	25.94
Mol ratio $\frac{\text{silica}}{\text{sesquioxide}}$	3.12	3.33	2.86
Available nutrients:			
Total N, per cent	0.111	0.019	0.020
0.05N HCl Soluble K, ppm	500	364	400
0.05N HCl Soluble Ca, ppm	1610	930	1180
0.05N HCl Soluble Mg, ppm	612	830	798
Available phosphorus, ppm.			
1:15 Soil: acid	22.5	7.5	22.5
1:100 Soil: acid	30.0	25.0	10.0
1:100 Soil: water	1.0	3.0	1.0
Exchangeable H+, m.e./100g soil	0.75	1.00	0.25
Total exchange, m.e./100g soil	17.10	10.28	12.84
Degree of saturation, per cent	95.6	100.0	98.8
pH	6.75	7.40	7.60

* Harris silty clay loam—The surface is flat and covered with blue stem and wire grass. Sedges, rushes, etc., grow in lower spots. The elevation is only a few inches above Lake Calcasieu. Sampled at the junction of the tidal marsh and coastal prairie three miles north of Hackberry, Louisiana, Cameron Parish:

A. 0-11 inches. Dark, grayish-brown, silty clay loam having a slightly blocky structure.
B. 11-22 inches. Dark gray mottled with yellowish-brown very fine sandy clay containing a few iron concretions. Due to wet conditions no structural development was evident.
C. 22-36 inches. Light gray mottled with yellow, very plastic clay showing no structure.

FIGURE 4. CROWLEY SILTY CLAY LOAM

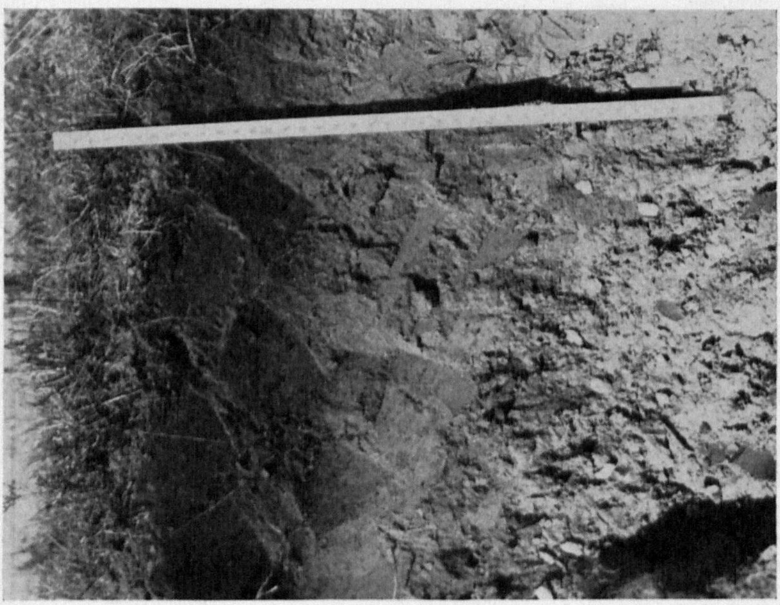

FIGURE 3. LAKE CHARLES CLAY LOAM

sections of poorly drained Sharkey in profile appearances. The total and available analyses of the Harris silty clay loam indicate that it should be productive. In areas where the soil can be drained and cultivated this has been found to be true. The Harris soils, where there is any appreciable elevation, are low in chlorides and show no unusual structural development that would indicate any definite relation to degraded alkali soils.

The Iberia clay (table 3) is not far removed from the Sharkey soils. It has developed normally as a third type back from the Bayou Teche. This position

TABLE 3. ANALYSES OF IBERIA SILTY CLAY LOAM*

	Iberia A Per Cent	Iberia B Per Cent	Iberia C Per Cent
Total analysis:			
SiO_2	78.58	71.25	74.50
TiO_2	0.56	0.50	0.42
Fe_2O_3	2.65	3.71	4.23
Al_2O_3	8.97	9.97	11.34
MnO	0.065	0.065	0.099
CaO	2.39	5.88	2.08
MgO	0.75	1.18	1.11
K_2O	1.05	1.00	1.27
Na_2O	1.05	0.97	1.14
P_2O_5	0.051	0.036	0.053
SO_3	0.380	0.140	0.243
Cl	0.054	0.030	0.040
Ignition loss	4.15	5.89	3.95
Colloid analysis:			
Colloid fraction	19.20	23.00	22.88
Ignition loss	19.10	11.86	11.06
SiO_2	47.20	49.30	50.04
Fe_2O_3	6.54	7.82	8.46
Al_2O_3	21.10	25.14	28.28
Mol ratio $\frac{\text{silica}}{\text{sesquioxide}}$	3.12	2.74	2.49
Available nutrients:			
Total N, per cent	0.125	0.065	0.039
0.05N HCl Soluble K, ppm.	240	180	140
0.05 HCl Soluble Ca, ppm.	3200	8880	3560
0.05N HCl Soluble Mg, ppm.	430	820	400
Available phosphorus, ppm.			
1:10 Soil: acid	12.0	0.17	2.0
1:40 Soil: acid	18.0	0.0	13.2
1:100 Soil: acid	20.0	0.0	20.0
1:100 Soil: water	trace	trace	trace
Exchangeable H+, m.e./100g soil	0.73	0.0	0.73
Total exchange, m.e./100g soil	18.2	18.7	18.5
Degree of saturation, per cent	95.9	100	97.8
pH	7.2	8.1	8.0

* Iberia silty clay loam—Virgin soil sampled in a field two miles south of Jeanerette, Louisiana, Iberia Parish.

A. 0.9 inches. Dark gray to grayish-black silty clay loam, fairly friable.

B. 9-26 inches. Grayish yellow mottled with rusty brown, silty clay, plastic and tenacious, containing some lime concretions in the lower B.

C. Below 26 inches. Yellowish, lighter-textured material containing numerous large lime concretions.

indicates that the material comprising this type was deposited from overflow waters from the Bayou Teche (19). The boundary between this and the Sharkey soil in Iberia Parish is sometimes imperceptible, especially on the east side of the Teche. Usually the Iberia has a very gentle slope away from the Teche, while there is little relief within the Sharkey. The two can be distinguished from one another

TABLE 4. ANALYSES OF LAKE CHARLES CLAY LOAM*

	Lake Charles A Per Cent	Lake Charles B Per Cent	Lake Charles C Per Cent
Total analysis:			
SiO_2	71.80	79.60	72.80
TiO_2	0.16	0.24	0.33
Fe_2O_3	2.59	2.70	3.83
Al_2O_3	14.00	10.90	15.25
MnO	0.011	0.004	0.008
CaO	1.86	1.74	1.67
MgO	0.94	1.05	1.05
K_2O	0.41	0.40	0.56
Na_2O	0.49	0.71	0.98
P_2O_5	0.071	0.040	0.051
SO_3	0.189	0.189	0.171
Ignition loss	7.60	3.01	3.72
Colloid analysis:			
Colloid fraction	44.20	34.32	47.80
Ignition loss	16.50	9.44	8.50
SiO_2	49.28	52.84	52.44
Fe_2O_3	4.56	6.64	6.94
Al_2O_3	26.98	27.86	28.56
Mol ratio $\frac{\text{silica}}{\text{sesquioxide}}$	2.76	2.75	2.66
Available nutrients:			
Total N, per cent	0.242	0.050	0.028
0.05N HCl Soluble K, ppm	240	110	166
0.05N HCl Soluble Ca, ppm	2600	1400	2000
0.05N HCl Soluble Mg, ppm	500	500	600
Available phosphorus, ppm.			
1:10 Soil: acid	3.6	2.6	3.1
1:40 Soil: acid	11.6	8.8	10.1
1:100 Soil: acid	24.0	19.0	22.0
1:100 Soil: water	0.5	0.2	0.5
Exchangeable H+, m.e./100g soil	6.37	2.05	1.00
Total exchange, m.e./100g soil	31.2	15.6	24.7
Degree of saturation, per cent	79.8	86.8	96.0
pH	5.7	6.6	7.3

* Lake Charles clay loam—Virgin prairie soil sampled on the right-of-way along U. S. Highway No. 90, two miles west of Jennings, Louisiana, Jefferson Davis Parish.

A. 0-10 inches. Very dark brown to black clay loam, finely granular structure.

B. 10-36 inches. Mottled brown and red clay, sticky and tenacious, containing many small iron concretions.

C. Below 36 inches. Yellow, somewhat mottled with red and gray, sticky plastic clay, rather compact, containing some iron and lime concretions.

TABLE 5. ANALYSES OF CROWLEY SILTY CLAY LOAM

	Crowley A Per Cent	Crowley B Per Cent
Total analysis:		
SiO_2	81.14	77.17
TiO_2	0.35	0.35
Fe_2O_3	3.13	3.41
Al_2O_3	7.00	9.98
MnO	0.24	0.17
CaO	0.84	0.93
MgO	0.42	0.46
K_2O	0.78	0.79
Na_2O	0.78	0.60
P_2O_5	0.025	0.023
SO_3	0.193	0.210
Cl	0.01	0.01
Ignition loss	5.15	5.77
Colloid analysis:		
Colloid fraction	24.10	38.30
Ignition loss	12.08	9.70
SiO_2	54.38	54.02
Fe_2O_3	6.46	6.54
Al_2O_3	24.42	26.46
Mol ratio $\frac{\text{silica}}{\text{sesquioxide}}$	3.19	2.95
Available nutrients:		
Total N, per cent	0.080	0.0805
0.05N HCl Soluble K, ppm.	61.2	74.0
0.05N HCl Soluble Ca, ppm.	1200	644
0.05N HCl Soluble Mg, ppm.	632	516
Available phosphorus, ppm.		
1:15 Soil: acid	0.50	0.50
1:40 Soil: acid	1.40	1.40
1:100 Soil: acid	4.50	4.50
1:100 Soil: water	trace	trace
Exchangeable H+, m.e./100g soil	9.1	11.2
Total exchange, m.e./100g soil	18.9	21.3
Degree of saturation, per cent	51.9	47.4
pH	7.1	6.1

* Crowley silty clay loam—Typical prairie soil sampled on the Rice Experiment Station near Crowley, Louisiana, from a plot that has been cultivated in rice for the past 40 years, Acadia Parish.

A. 0-6 inches. Dark gray with brown iron stains around the channels of old roots, silty clay loam, platy structure, numerous dark, hard, round iron concretions. Tongues of ashy gray material extend from this horizon to a depth of 20 inches or more.

B. 6-23 inches. Light gray streaked with brown, compact, silty clay loam, coarsely granular structure. At about 15 inches this grades into a purplish brown mottled with red, compacted clay, blocky to columnar structure.

C. Below 23 inches. Mottled gray and yellow plastic clay, small number of iron concretions.

by the yellowish subsoil of the Iberia, which usually carries lime concretions, and by the distinct mottling in the surface soil of the Sharkey.

The Lake Charles clay loam (table 4) has been considered to be of different origin from the Iberia and is mapped in entirely separate localities, there being

TABLE 6. ANALYSES OF CROWLEY SILTY CLAY LOAM*

	Crowley A Per Cent	Crowley B Per Cent	Crowley C Per Cent
Total analysis:			
SiO_2	78.50	75.60	67.14
TiO_2	0.60	0.48	0.48
Fe_2O_3	1.70	3.45	4.17
Al_2O_3	7.85	11.37	15.63
MnO	0.22	0.03	0.06
CaO	0.72	0.83	1.33
MgO	0.43	0.54	0.79
K_2O	0.42	0.41	0.93
Na_2O	0.66	1.08	0.73
P_2O_5	0.032	0.027	0.031
SO_3	0.245	0.245	....
Cl	0.00	0.02	0.00
Ignition loss	7.43	5.43	7.45
Colloid analysis:			
Colloid fraction	22.40	38.70	48.88
Ignition loss	16.20	10.26	10.20
SiO_2	50.18	52.40	51.10
Fe_2O_3	4.94	9.98	9.98
Al_2O_3	24.32	25.22	25.56
Mol ratio $\frac{\text{silica}}{\text{sesquioxide}}$	3.06	2.78	2.70
Available nutrients:			
Total N, per cent	0.201	0.110	0.120
0.05N HCl Soluble K, ppm	100	32.5	90.4
0.05N HCl Soluble Ca, ppm	820	520	1080
0.05N HCl Soluble Mg, ppm	294	325	702
Available phosphorus, ppm.			
1:15 Soil: acid	1.25	0.75	0.75
1:40 Soil: acid	3.00	1.60	1.60
1:100 Soil: acid	12.5	6.00	6.00
1:100 Soil: water	trace	trace	trace
Exchangeable H+, m.e./100g soil	9.7	11.4	11.0
Total exchange, m.e./100g soil	19.9	22.0	28.9
Degree of saturation, per cent	51.2	48.2	61.9
pH	6.0	5.8	6.1

* Crowley silty clay loam—Virgin prairie soil sampled on the right-of-way of the Southern Pacific Railroad along U. S. Highway No. 90, two miles west of the Rice Experiment Station, Crowley, Louisiana, Acadia Parish.

A. 0-6 inches. Dark gray friable silty clay loam, finely granular structure, no compaction. Ashy gray tongues are fewer than in the cultivated soil.

B. 6-23 inches. Brownish gray silty clay loam, granular to columnar structure.

C. Below 23 inches. Mottled gray and yellow clay, small number of iron concretions.

no mention of association of one with the other (19) (29). There is, however, a striking similarity between the two soils in profile appearance and description and in actual chemical composition. If their origin is common, as suggested by Howe, this would be expected. Possibly with more investigation, the incorporation of these

TABLE 7. ANALYSES OF CROWLEY SILTY CLAY LOAM*

	Crowley A_1 Per Cent	Crowley A_2 Per Cent	Crowley B Per Cent	Crowley C Per Cent
Total analysis:				
SiO_2	77.25	80.66	80.30	73.65
TiO_2	0.30	0.35	0.37	0.40
Fe_2O_3	3.60	3.68	3.59	4.64
Al_2O_3	11.15	8.94	9.03	13.80
MnO	0.120	0.104	0.104	0.150
CaO	0.68	0.41	0.45	0.75
MgO	0.78	0.69	0.40	0.94
K_2O	1.21	1.37	0.89	1.44
Na_2O	0.26	0.17	0.22	0.21
P_2O_5	0.080	0.045	0.030	0.040
SO_3	0.24	0.16	0.23	0.18
Cl	0.039	0.030	0.020	0.030
Ignition loss	4.90	3.96	4.42	3.20
Colloid analysis:				
Colloid fraction	20.60	24.40	40.00	16.20
Ignition loss	16.60	12.40	11.64	8.06
SiO_2	48.68	49.32	47.20	51.78
Fe_2O_3	7.34	7.18	9.98	9.98
Al_2O_3	20.68	26.66	26.16	24.78
Mol ratio $\frac{\text{silica}}{\text{sesquioxide}}$	3.21	2.64	2.43	2.79
Available nutrients:				
Total N, per cent	0.144	0.087	0.071	0.027
0.05N HCl Soluble K, ppm.	192	168	154	292
0.05N HCl Soluble Ca, ppm.	964	1036	2140	2000
0.05N HCl Soluble Mg, ppm.	208	262	350	328
Available phosphorus, ppm.				
1:15 Soil: acid	1.5	1.5	1.5	1.5
1:100 Soil: acid	8.0	20.0	15.0	10.0
1:100 Soil: water	1.0	1.0	5.0	2.0
Exchangeable H+, m.e./100g soil	5.5	4.5	1.5	0.5
Total exchange, m.e./100g soil	12.2	11.68	17.3	16.46
Degree of saturation, per cent	55.0	61.4	91.4	97.0
pH	5.50	5.50	6.55	6.90

* Crowley silty clay loam—Virgin coastal prairie soil sampled from a field one mile west of Wright, Louisiana, Vermilion Parish.

A_1. 0-4 inches. Dark grayish brown friable silt loam.

A_2. 4-14 inches. Lighter gray speckled with brown friable but slightly cemented silt loam, containing a few iron concretions.

B. 14-26 inches. Dark brown mottled with red and containing spots of limonite, compacted clay, blocky structure.

C. Below 26 inches. Yellow mottled with gray and red, heavy plastic clay.

two series into one would be a step forward in clarifying the relationship between these soils.

The Crowley series is the most predominant of all the prairie soils and the one on which most of the rice is grown. Total and available analyses are therefore presented for three different samples of the Crowley silty clay loam. Tables 5 and 6

TABLE 8. ANALYSES OF OLIVIER SILT LOAM*

	Olivier A Per Cent	Olivier B Per Cent	Olivier C Per Cent
Total analysis:			
SiO_2	79.35	78.70	73.60
TiO_2	0.40	0.35	0.45
Fe_2O_3	2.75	2.84	4.19
Al_2O_3	9.97	12.23	11.94
MnO	0.02	0.01	0.04
CaO	0.66	0.78	1.12
MgO	0.61	0.68	0.79
K_2O	0.62	0.60	0.92
Na_2O	0.41	0.32	0.46
P_2O_5	0.028	0.03	0.034
SO_3	0.10	0.08	0.12
Cl	0.02	0.01	0.02
Ignition loss	4.72	3.79	5.11
Colloid analysis:			
Colloid fraction	19.16	18.60	21.00
Ignition loss	16.00	12.22	12.70
SiO_2	48.30	49.42	50.40
Fe_2O_3	7.10	6.86	6.70
Al_2O_3	25.70	27.26	29.00
Mol ratio $\frac{\text{silica}}{\text{sesquioxide}}$	2.67	2.61	2.53
Available nutrients:			
Total N, per cent	0.104	0.048	0.050
0.05N HCl Soluble K, ppm	130	150	106
0.05N HCl Soluble Ca, ppm	1150	600	894
0.05N HCl Soluble Mg, ppm	424	358	566
Available phosphorus, ppm.			
1:15 Soil: acid	2.3	1.5	1.7
1:100 Soil: acid	10.0	6.0	11.0
1:100 Soil: water	4.0	3.0	5.0
Exchangeable H+, m.e./100g soil	4.40	5.48	6.78
Total exchange, m.e./100g soil	11.50	10.50	13.62
Degree of saturation, per cent	61.80	47.80	50.20
pH	6.2	5.3	5.4

* Olivier silt loam—Sampled from pasture which is planted to rice on alternate years. Located two miles west of Opelousas, St. Landry Parish.

A. 0-10 inches. Brownish gray friable silt loam, few iron concretions.

B. 10-30 inches. Lighter gray somewhat mottled with rusty brown, less friable, silty clay loam containing many more iron concretions.

C. Below 30 inches. Mottled gray and yellowish brown compact clay, somewhat less concretionary material.

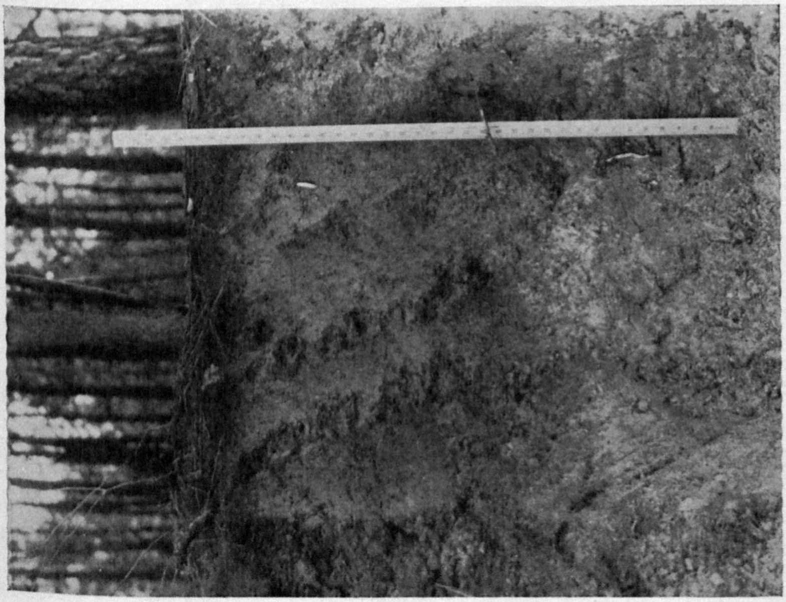

FIGURE 6. KATY VERY FINE SANDY LOAM

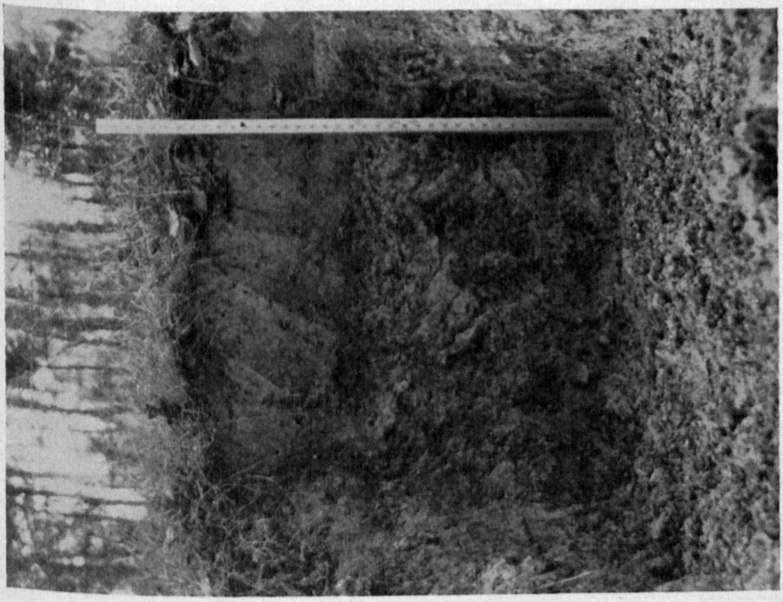

FIGURE 5. CALCASIEU VERY FINE SANDY LOAM

contain the analyses of a Crowley silty clay loam that has been continually cultivated to rice for forty years at the Rice Experiment Station at Crowley, Louisiana, and of a virgin Crowley from an adjacent area. These analyses indicate that changes have occurred in the soil as a result of continual cultivation and flooding. There has been a marked decrease in nitrogen in the cultivated soil, particularly in the A horizon. There has been some loss in total phosphorus, which was probably removed by crops. The available phosphorus has decreased, although it was quite low in the virgin soil. The other sample of Crowley soil (table 7) was also taken in the virgin condition from an area 15 miles south of Crowley, Louisiana. In this area

TABLE 9. ANALYSES OF CALCASIEU VERY FINE SANDY LOAM*

	Calcasieu A Per Cent	Calcasieu B Per Cent	Calcasieu C Per Cent
Total analysis:			
SiO_2	89.40	73.40	77.50
TiO_2	0.20	0.20	0.25
Fe_2O_3	1.58	3.66	3.22
Al_2O_3	5.12	15.42	12.65
MnO	0.013	0.006	0.004
CaO	1.30	1.06	1.38
MgO	0.32	0.34	0.47
K_2O	0.36	0.50	0.56
Na_2O	0.05	0.04	0.04
P_2O_5	0.027	0.020	0.013
SO_3	0.07	0.05	0.05
Cl	0.018	0.020	0.015
Ignition loss	2.25	5.58	4.44
Colloid analysis:			
Colloid fraction	14.52	44.92	40.00
Ignition loss	13.04	10.06	9.60
SiO_2	49.40	49.20	50.10
Fe_2O_3	7.02	7.50	7.10
Al_2O_3	28.14	30.52	30.20
Mol ratio $\frac{\text{silica}}{\text{sesquioxide}}$	2.54	2.33	2.42
Available nutrients:			
Total N, per cent	0.056	0.050	0.035
0.05N HCl Soluble K, ppm	246	270	262
0.05N HCl Soluble Ca, ppm	360	286	438
0.05N HCl Soluble Mg, ppm	236	230	262
Available phosphorus, ppm.			
1:15 Soil: acid	1.2	0.9	0.9
1:100 Soil: acid	17.0	20.0	18.0
1:100 Soil: water	1.0	1.0	1.0
Exchangeable H+, m.e./100g soil	4.5	15.5	11.5
Total exchange, m.e./100g soil	9.12	19.7	17.1
Degree of saturation, per cent	50.7	21.3	32.7
pH	4.80	4.75	5.00

* Calcasieu very fine sandy loam—Virgin soil, surface flat with small elevated ridges. Sampled in wooded area (pine, hickory) 0.3 miles southeast of U. S. Highway No. 90 at the Lake Charles bridge over Lake Calcasieu, Calcasieu Parish.

A. 0-18 inches. Brown friable very fine sandy loam. A_2 is a grayish brown mottled with gray, fairly friable very fine sandy loam, containing iron concretions and noticeably bleached ashy gray spots.

B. 18-26 inches. Gray mottled with red, heavy plastic clay showing nutty structure, some whitish gray pockets projecting into this layer.

C. 26-48 inches. Dark gray mottled with yellow and red, plastic clay containing no concretionary material.

the soils are more productive, and the yields of rice have been slightly higher than in the region further north. The analyses show also that this sample is distinctly higher in total and available phosphorus than the other two samples of Crowley silty clay loam.

The Olivier series is considered as derived from old Mississippi alluvium or terrace material. These soils are bounded on one side by the Mississippi first bottom soils of more recent alluvium and on the other side by the coastal prairie soils, which have been said to represent marine sediments. Much of the rice grown in the northeastern section of the rice area is on the so-called gray or prairie phase of Olivier. The appearances and analyses of a typical soil of this series (table 8) indicate quite a close relationship between the Olivier and the Crowley soils. The Olivier is not as impervious in the lower subsoil, but is usually no more productive. In localities where the two series are associated, it is difficult to differentiate between them.

There occur in the northern portion of the coastal prairie a number of closely related terrace soils that may be considered as older than the soils described above. Chief among these are the Acadia, Calcasieu, and Katy (tables 9 and 10). These soils are not very extensively cultivated. Some rice is grown on Katy, but the area for the most part is covered by native forest growth. The Acadia and Calcasieu soils occur as narrow borders along the principal streams and widen out into extensive areas where conditions for terrace formation were favorable. The character of their formation and their greater elevation have allowed more rapid weathering and freer percolation of water through the soils. The Acadia differs from the Katy and Calcasieu in that lime concretions are evident in the B or upper C horizons. Distinction between Katy and Calcasieu is difficult to make. It is the opinion of the authors that these series might well be considered as a single series.

In considering all of the preceding tables collectively, several facts of interest may be noted in addition to those discussed in presenting each table. Generally silica is highest in the A horizon, while the amounts of iron and aluminum are greater in the lower horizons. The sulfur content of these soils is high. The available nutrient studies indicate that the soils are fairly high in exchangeable or available potassium. While the depleted Crowley silty clay loam at the Rice Experiment Station was an exception to this high level, little response of rice to potash fertilization has been found in controlled experiments with the soil. Only two soils of the rice area, the Katy and the Calcasieu, were found to be low in the degree of saturation. Both of these soils dropped below 50 per cent saturation, which indicates a definite acid condition. From the analysis of the prairie soils for readily available phosphorus, it appears that this element is frequently the limiting nutrient for plant growth. The effects of phosphate fertilization on the growth of rice have been questionable, but the responses of all upland crops grown on these soils to applications of phosphorus have been marked.

In recent years many soil scientists have concluded that the analysis of the clay fraction gives results that are of much more fundamental value than a complete analysis of the total soil. The clay fraction is presumed to be identifiable with the weathering complex. Analyses of this fraction offer a clue to soil properties and are of significance from the standpoint of the genetic classification of soils. For these reasons, the percentage of colloidal clay was determined, and it was extracted and analyzed for ignition loss, silica, alumina, and ferric oxide. From these results the molecular ratio of silica to sesquioxides was computed. These colloid analyses and molecular ratios are listed for each soil in tables 1 through 10. From a general consideration of these analyses, several facts are evident. The per cent of silica in the colloid increases slightly with increasing depth. The per cents of alumina and ferric oxide also increase with increasing depth, but to a greater extent than silica. There is, therefore, a decrease in the molecular ratio of silica to sesquioxide in the

TABLE 10. ANALYSES OF KATY VERY FINE SANDY LOAM*

	Katy A_1 Per Cent	Katy A_2 Per Cent	Katy B Per Cent	Katy C Per Cent
Total analysis:				
SiO_2	86.30	83.70	73.70	80.10
TiO_2	0.15	0.10	0.10	0.20
Fe_2O_3	2.19	4.03	4.20	3.00
Al_2O_3	4.99	7.43	14.55	11.30
MnO	0.104	0.078	0.003	0.026
CaO	1.84	1.28	1.26	1.35
MgO	0.61	0.64	0.76	0.56
K_2O	0.38	0.40	0.44	0.55
Na_2O	0.04	0.05	0.03	0.04
P_2O_5	0.061	0.055	0.015	0.031
SO_3	0.06	0.04	0.04	0.04
Cl	0.015	0.018	0.015	......
Ignition loss	3.63	2.83	4.87	2.95
Colloid analysis:				
Colloid fraction	15.00	17.00	37.72	30.40
Ignition loss	26.30	13.42	9.50	9.14
SiO_2	40.48	45.70	46.06	49.10
Fe_2O_3	6.30	7.58	8.94	8.46
Al_2O_3	25.53	29.90	29.76	28.06
Mol ratio $\frac{\text{silica}}{\text{sesquioxide}}$	2.30	2.20	2.18	2.45
Available nutrients:				
Total N, per cent	0.090	0.045	0.052	0.024
0.05N HCl Soluble K, ppm	168	126	154	154
0.05N HCl Soluble Ca, ppm	428	214	858	930
0.05N HCl Soluble Mg, ppm	186	196	370	480
Available phosphorus, ppm.				
1:15 Soil: acid	1.5	1.5	1.5	1.5
1:100 Soil: acid	10.0	20.0	40.0	50.0
1:100 Soil: water	2.0	10.0	10.0	20.0
Exchangeable H+, m.e./100g soil	6.0	5.75	5.5	2.0
Total exchange, m.e./100g soil	9.76	8.12	16.74	13.62
Degree of saturation, per cent	38.5	29.2	67.2	85.3
pH	5.00	4.90	5.45	5.85

* Katy very fine sandy loam—Virgin soil in flatwoods (pine, oak, hickory). Sampled 1.5 miles east of Nezpique Bayou on the Oberlin to Mamou highway, Allen Parish.

A_1. 0-8 inches. Dark grayish brown friable very fine sandy loam, few iron concretions.

A_2. 8-17 inches. Lighter, yellowish to grayish brown, less friable, very fine sandy loam having a more platy structure, containing many more iron concretions.

B. 17-33 inches. Mottled yellow and red, compact plastic clay having a coarsely granular to nutty structure.

C. 33-48 inches. Yellow plastic very fine sandy clay to clay.

colloid as the depth increases from the A to the C horizon. This relationship did not hold for the more fully developed Katy and Calcasieu soils, where the silica-sequioxide ratio was higher in the C than in the B horizon.

In general, the productivity of these soils decreases in the order of their presentation in the tables. An arrangement in the order of decreasing productivity coincides with the most natural grouping according to age and degree of weathering as evidenced by the profile characteristics. This coincidence seems to substantiate the theory of a common alluvial origin. There appears to be a definite gradation from the older and more mature terrace soil, the Katy or Calcasieu, through the Crowley, Lake Charles, and Iberia, to the present Mississippi first bottom soil, the Sharkey.

A comparison of the phosphorus contents of these soils, both total and available, shows that all of the so-called prairie soils are inherently low in this element, while the Sharkey is relatively high. This is no serious objection to the theory of alluvial origin, however, for some terrace soils of the present Mississippi delta, such as the Olivier, are much lower in phosphorus than the Sharkey.

Typical soils from the rice areas of Arkansas and of Texas were analyzed for available nutrients for the purpose of comparing the levels of fertility in these soils with those of Louisiana. The results show that there are comparatively little differences in the nutrient levels of samples taken from the same or closely related types in the different states.

The Influences of Flooding on the Chemical and Physical Properties

It has been maintained by some investigators that the changes induced in the rice soil by flooding are a result of the type of water used. Some of the waters used for irrigation of rice have been analyzed and reported (6). In table 11 are presented

TABLE 11. ANALYSES OF WATERS USED FOR IRRIGATION OF RICE

	Parts per Million				
Constituent	Longman's Well[2]	Heinen's Field[2]	Crowley Sta. Well[1]	Crowley Sta. Well[2]	N. John Well[1]
Total solids	1150.0	328.0	400.0	410.0	339.0
Organic solids	72.0	75.0	50.5	77.0	174.0
SiO_2 (total)	35.0	44.0	30.2	30.0	26.4
PO_4	00.2	0.1	0.5	0.3	0.8
R_2O_3	55.0	14.0	6.7	36.0	9.0
Fe	1.2	0.4	3.0	2.0	0.9
Al	28.0	7.4	0.3	17.5	0.25
Mn	trace	trace	trace	trace	trace
Ti	0.0	0.0	0.0	0.0	0.0
Ca	113.0	54.0	63.2	77.0	57.2
Mg	22.8	25.6	10.6	10.7	18.0
Na	114.4	59.0	60.4	72.0	95.6
K	18.0	24.0	13.6	34.0	115.0
SO_4	7.0	4.0	6.0	6.0	5.6
HCO_3	310.0	200.0	300.0	320.0	519.0
CO_3	0.0	0.0	0.0	0.0	0.0
Cl	482.0	30.0	29.7	28.0	60.0
H_2S	0.0	0.0	0.0	0.0	0.0
pH	7.4	7.6	7.2	7.2	7.4

[1] Water sampled August, 1934. [2] Water sampled July, 1935.

TABLE 12. STUDY OF THE EFFECT OF FLOODING ON CROWLEY SILTY CLAY LOAM

No. Treatment	pH				SiO_2				R_2O_3				Fe				Al			
	A*	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
1. Virgin (opt.)	5.00	4.97	5.00	5.05	......	260	200	300	....	80	90	50	....	33	20	†	....	20	40	....
2. Virgin (flood)	5.05	6.14	6.35	6.55	150	175	175	200	50	110	115	38	....	65	50	†	....	15	45	....
3. Defloc. (opt.)	6.45	6.40	6.25	6.50	......	800	400	1750	......	80	115	120	....	50	30	†	....	8	50	....
4. Defloc. (flood)	6.70	6.97	6.97	7.27	480	160	200	170	100	60	90	95	....	33	20	†	....	8	40	....
5. Defloc.+O.M. (opt.)	6.70	6.66	6.50	6.70	......	625	300	1300	......	100	90	60	....	41	20	†	....	21	40	....
6. Defloc.+O.M. (flood)	7.12	7.13	7.00	7.30	118	120	160	380	65	75	75	110	....	33	20	†	....	16	30	....
2. Virgin (flood). Drain from bottom	......	6.18	6.30	8.10	......	20	45	48	....	210	155	165	....	185	86	84	....	13	18	....
4. Defloc. (flood). Drain from bottom	......	7.40	7.75	8.30	......	100	156	100	....	20	80	66	....	9	46	45	....	5	8	....
6. Defloc.+O.M. (flood). Drain from bottom	......	7.70	8.30	8.75	......	110	170	120	....	50	70	50	....	20	46	33	....	....	3	....

TABLE 12. STUDY OF THE EFFECT OF FLOODING ON CROWLEY SILTY CLAY LOAM—CONTINUED

No. Treatment	Ca				Mg				Na				K			
	A*	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
1. Virgin (opt.)	....	36	32	32	....	17	25	21	....	7	3	12	....	80	100	70
2. Virgin (flood)	25	44	50	40	16	19	44	49	22	23	27	36	53	65	80	70
3. Defloc. (opt.)	....	44	39	41	....	23	23	58	....	39	49	66	....	80	100	80
4. Defloc. (flood)	25	36	39	59	14	28	35	48	57	69	47	71	60	70	80	70
5. Defloc.+O.M. (opt.)	....	27	50	72	....	19	33	59	....	96	50	95	....	100	110	110
6. Defloc.+O.M. (flood)	100	116	50	50	42	30	33	50	67	50	25	77	80	100	100	90
2. Virgin (flood). Drain from bottom	....	42	42	23	....	14	15	12	....	37	17	19	....	80	80	70
4. Defloc. (flood). Drain from bottom	....	72	158	133	....	8	50	56	....	151	145	36	....	50	28	40
6. Defloc.+O.M. (flood). Drain from bottom	....	236	186	34	....	100	57	20	....	139	120	32	....	60	40	45

* A—Two days after flooding; B—Three weeks after flooding; C—Nine weeks after flooding; D—Eighteen weeks after flooding. Results expressed as parts per million parts of soil. In the drained pots results are expressed as parts per million parts of displaced solution.

† Only a trace if present.

some more recent analyses of irrigation waters from the well at the Rice Experiment Station at Crowley and from some of the locations that have been under observation because of trouble claimed from so-called "alkali spots." In only one of these cases, that at Longman's, can it be said that the trouble could be traced fairly definitely to the water used for flooding. In all other cases the salinity or alkalinity of the well water is not beyond what is ordinarily called a permissible allowance (7) (27).

The set-up for the study of the influences of flooding on the hydrolysis, the solution, or the decomposition of the complex silicates has been previously outlined under "Experimental Procedure." In this study distilled water was used. A summation of the data obtained is presented in table 12. An examination of these data shows that there were a number of changes in the soil for which the water itself, or its dissociation products, was responsible. In the first place, there was a decided increase in pH and alkalinity in all cases of flooding, while in the case of soil kept at optimum moisture the pH did not vary significantly. The pH of the virgin soil in flooded condition increased steadily from 5.00 to 6.55 after 18 weeks of flooding with distilled water. The pH of the cultivated soil was higher to begin with, but even so it increased under flooded conditions from 6.45 to 7.27. The pH of the displaced solutions which were drained from the bottoms of the pots was much higher than that of the soil as determined by sampling with a tube and determining in 1 to 5 water suspension. The pH showed a slight tendency to rise in the presence of organic matter. In the solution drained from the flooded pots the pH rose above 8.0 in all cases, and in the case of the solution from the cultivated soil plus organic matter, it reached the unusual value of 8.75.

In comparing the results obtained for silica (table 12) it must be remembered, as explained in the experimental procedure, that difficulty was encountered in obtaining a clear extract. These figures, therefore, really represent a residue on evaporating and re-solution. Contrary to expectation, the soil that was kept at optimum conditions was much slower filtering and gave a more highly colloidal extract than the soil kept flooded. From the analyses of the displaced solutions, the tendency of the soluble and colloidal silica content to increase in the virgin soil after flooding is obvious. It is also evident that the silica content of the solution drained from the cultivated soil was much higher than that of the solution from the virgin soil.

The troubles involved in arriving at a method of soluble-iron determination have been mentioned. The iron is in solution in the ferrous form and may be largely colloidal. In any attempt at filtration much of the iron is oxidized to the ferric state and removed from solution. Nevertheless, certain conclusions can be drawn from the results listed in table 12 under R_2O_3, Fe, and Al, particularly from the determinations on displaced solution in which no filtration was performed and on which the analyses were run immediately upon collection. The solution of iron was greater in the presence of organic matter and was noticeably higher in the displaced solution of the virgin soil. After the first few weeks the iron in solution decreased in all cases, possibly due to the decrease in actively decomposing organic matter.

Where organic matter had been added, the amounts of calcium and magnesium in solution increased in the soil that was flooded but did not increase when the soil was kept at optimum moisture. In the first few weeks after flooding the amounts of both were particularly high. After nine weeks of flooding the amounts in solution tended to drop to the level of the amounts of calcium and magnesium in the soils not treated with organic matter. In the case of the virgin soil, flooding did not appear to have much effect on the solution of calcium but did increase the solution of magnesium.

TABLE 13. EFFECT OF VARIOUS TREATMENTS ON PERCOLATION IN A CROWLEY SILTY CLAY LOAM

No.	Treatment	Average Head Yield. Per Cent Gain or Loss	Percolation in cc. per Hour at Intervals After Flooding 6 Days	29 Days	54 Days	13 Months	16 Months	20 Months
1.	Check, no treatment	0.0	0.0	0.0	0.0	3.5	0.8	1.8
2.	0.80% organic matter	+127.8	0.0	5.1	0.9	10.0	19.0	150.0
3.	0.20% $CaSO_4.2H_2O$	−51.7	0.0	2.6	1.4	8.5	2.1	2.5
4.	0.12% $CaCO_3$	−7.7	0.0	0.0	2.3	10.0	4.3	7.0
5.	0.04%S and 0.12% $CaCO_3$	−32.7	2.4	5.9	4.2	70.0	15.0	100.0
6.	0.04%S	−46.2	0.0	0.0	1.1	24.0	12.0	8.0
7.	0.20% $CaSO_4$ and 0.80% organic matter	+140.5	29.4	13.0	2.2	29.5	38.0	170.0
8.	0.12% $CaCO_3$ and 0.80% organic matter	+106.7	27.5	12.0	2.2	34.0	25.0	200.0
9.	0.04%S and 0.80% organic matter	+98.2	15.8	6.8	0.5	124.0	56.0	220.0
10.	0.04%S and 0.80% organic matter and 0.12% $CaCO_3$	+137.9	40.2	8.3	3.7	53.5	45.0	180.0

TABLE 14. EFFECT OF VARIOUS TREATMENTS ON AGGREGATION IN A CROWLEY SILTY CLAY LOAM

No.	Treatment	Average Head Yield, Per Cent Gain or Loss	Per Cent Distribution of Aggregates 20 Months After Flooding 2.0 mm.	2.0-1.0	1.0-0.5	0.5-.25	.25-.10	Total >0.10 mm.	Average Percolation over 20 months cc./hour
1.	Check, no treatment	0.0	1.8	1.8	3.8	3.0	7.7	18.1	0.9
2.	0.8% organic matter	+127.8	4.9	2.9	5.5	3.4	9.5	30.2	85.0
3.	0.20% $CaSO_4.2H_2O$	−51.7	3.3	2.3	4.5	3.0	7.9	21.0	2.3
4.	0.12% $CaCO_3$	−7.7	1.4	2.4	5.2	4.8	10.4	24.2	5.8
5.	0.04%S and 0.12% $CaCO_3$	−32.7	3.0	3.4	6.0	3.6	7.0	23.0	58.0
6.	0.04%S	−46.2	2.2	2.0	5.0	3.0	6.8	19.0	10.0
7.	0.20% $CaSO_4$ and 0.80% organic matter	+140.5	8.4	4.1	6.1	4.2	9.2	32.0	104.0
8.	0.12% $CaCO_3$ and 0.80% organic matter	+106.7	2.5	2.3	7.2	5.6	11.0	28.6	113.0
9.	0.04%S and 0.80% organic matter	+98.2	7.4	3.0	8.0	4.4	8.0	30.8	138.0
10.	0.04%S and 0.80% organic matter and 0.12% $CaCO_3$	+137.9	4.7	2.6	5.2	3.5	7.9	23.9	113.0
X.	Untreated Crowley soil, which has been continually cultivated	....	0.0	2.0	3.0	1.6	4.4	11.0	....
Y.	Virgin Crowley soil, presumably never cultivated	....	6.8	20.0	21.4	9.0	11.0	68.2	....

The higher original content of the sodium in solution in the cultivated soil is apparent. The increase of sodium in solution in the virgin soil upon flooding is also evident. Whether this increase is due to hydrolysis of the complex silicates, or to carbonation and solution induced by the decomposition of the organic matter, cannot be stated. Since distilled water was used, however, it is certain that the changes could not have been due to additions of salts through the water used for flooding. Evidently the change in the chemical nature and resultant physical changes in these rice soils as a result of prolonged flooding can be partially accounted for by increased hydrolysis with the liberation of sodium ions.

The results obtained in efforts to improve the physical condition of these rice soils are summed up in tables 13 and 14. The rates of percolation were consistent as a whole and several facts of interest are worth noting. Percolation was considerably better and the yield was greater in treatments where organic matter was applied. The calcium carbonate treatment was relatively ineffective in increasing percolation and depressed the yield slightly. Gypsum was even less effective from both standpoints. In combination with organic matter, however, lime as well as gypsum appeared to be beneficial. The use of elemental sulfur in treatments increased percolation somewhat in later months and its use in combination with lime caused quite an increase, but the yields were decreased in both instances.

The data in table 14 shows the effects of treatments on aggregation, rate of percolation, and yield. The development of aggregates is associated with increased rate of percolation and increased yield. In the soil that had received treatments of organic matter, there was a noticeable improvement in physical condition and a tendency to form water-stable aggregates. At the bottom of table 14 are appended the results from aggregate analyses of samples of the cultivated Crowley silty clay loam and the virgin Crowley silty clay loam. These are inserted to bring out a comparative measurement of the physical degradation that has taken place in the cultivated soil, and to illustrate the two extremes that are possible in this soil. The marked difference in distribution of aggregates in these two soils is apparent.

CONCLUSIONS

1. The soils of the coastal prairie area of southwest Louisiana and those of the present Mississippi delta are in many respects alike in profile characteristics and show gradations in development in going from the newer to the older deposits.

2. The soils of the Iberia and Lake Charles series are very closely related and show many resemblances. The theory of a common alluvial origin appears to be well founded. The two series might well be incorporated in one.

3. The soils of the Calcasieu and Katy series, which have developed on older terraces, are very similar and should be incorporated in a single series.

4. Flooding a virgin Crowley soil with distilled water caused increases in the pH and in the contents of soluble sodium and magnesium. Flooding also caused increases in the contents of iron and silica in the displaced solution.

5. Continual flooding and cropping to rice over a period of years breaks down to a measurable extent the water-stable aggregates of the soil and causes a deflocculated physical condition.

6. The effect of various treatments on improvement in the physical condition of a cultivated Crowley soil was detected by measurements of the rate of percolation of water through the soil and by aggregate analysis.

7. The addition of leguminous organic matter was the most effective treatment for improvement of the physical condition. Applications of gypsum, lime, and elemental sulfur were much less effective.

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